**Chapter 24 Section 1 The Study of Light**

**Key Concepts**

* What types of radiation make up the electromagnetic spectrum?
* What can scientists learn about a star by studying its spectrum?
* How can astronomers determine whether a star is moving toward or away from Earth?

**Vocabulary**

* electromagnetic spectrum
* photon
* spectroscopy
* continuous spectrum
* absorption spectrum
* emission spectrum
* Doppler effect

**Reading Strategy**

**Predicting** Copy the table. Before you read, predict the meaning of the term electromagnetic spectrum. After you read, revise your definition if it was incorrect.

|  |  |  |
| --- | --- | --- |
| **Vocabulary Term** | **Before You Read** | **After You Read** |
| Electromagnetic Spectrum | a. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | b. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ |

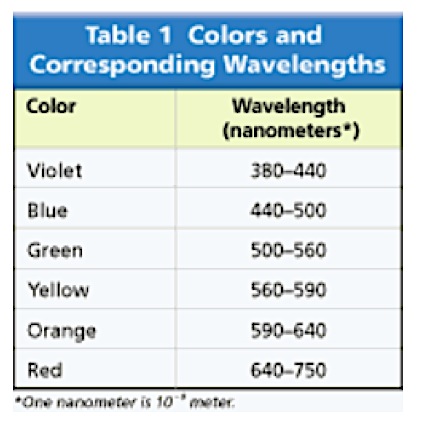
Astronomers are in the business of gathering and studying light. Almost everything that is known about the universe beyond Earth comes by analyzing light from distant sources. Consequently, an understanding of the nature of light is basic to modern astronomy. This chapter deals with the study of light and the tools used by astronomers to gather light in order to probe the universe. In addition, we will examine the nearest source of light, our sun. By understanding addition, we will examine the nearest source of light, our sun. By understanding how the sun works, astronomers can better grasp the nature of more distant objects in space.

**Electromagnetic Radiation**

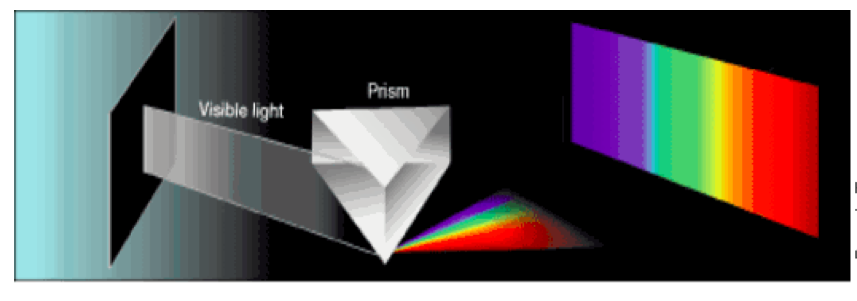
The vast majority of our information about the universe is obtained from the study of the light emitted from stars and other bodies in space. Although visible light is most familiar to us, it makes up only a small part of the different types of energy known as electromagnetic radiation. **Electromagnetic radiation includes gamma rays, X-rays, ultraviolet light, visible light, infrared radiation, microwaves, and radio waves.** The arrangement of these waves according to their wavelengths and frequencies is called the electromagnetic spectrum. Figure 1 shows the **electromagnetic spectrum**. All energy, regardless of wavelength, travels through the vacuum of space at the speed of light, or 300,000 kilometers per second. Over a 24-hour day, this equals a staggering 26 billion kilometers.

**Figure 1 Electromagnetic Spectrum** The electromagnetic spectrum classifies radiation according to wavelength and frequency. **Interpreting Diagrams** Which type of radiation has the shortest wavelength?

**Nature of Light**

Experiments have shown that light can be described in two ways. In some instances light behaves like waves, and in others like particles. In the wave sense, light can be thought of as swells in the ocean. This motion is characterized by a property known as wavelength, which is the distance from one wave crest to the next. Wavelengths vary from several kilometers for radio waves to less than a billionth of a centimeter for gamma rays, as shown in Figure 1. Most of these waves are either too long or too short for our eyes to see.

The narrow band of electromagnetic radiation we can see is sometimes called visible light. However, visible light consists of a range of waves with various wavelengths. This fact is easily demonstrated with a prism, as shown in Figure 2. As visible light passes through a prism, the color with the shortest wavelength, violet, is bent more than blue, which is bent more than green, and so forth. Thus, visible light can be separated into its component colors in the order of their wavelengths, producing the familiar rainbow of colors.

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**Figure 2** ***Spectrum*** A spectrum is produced when sunlight or visible light is passed through a prism, which bends each wavelength at different angles.

**Photons**

Wave theory, however, cannot explain some effects of light. In some cases, light acts like a stream of particles called **photons**. Photons can be thought of as extremely small bullets fired from a machine gun. They can push on matter. The force they exert is called radiation pressure. Photons from the sun are responsible for pushing material away from a comet to produce its tail. Each photon has a specific amount of energy, which is related to its wavelength in a simple way: Shorter wavelengths have more energetic photons. Thus, blue light has more energetic photons than does red light.

Which theory of light—the wave theory or the particle theory—is correct? Both, because each will predict the behavior of light for certain phenomena. As George Abell, a well-known astronomer, stated about all scientific laws, “The mistake is only to apply them to situations that are outside their range of validity.”

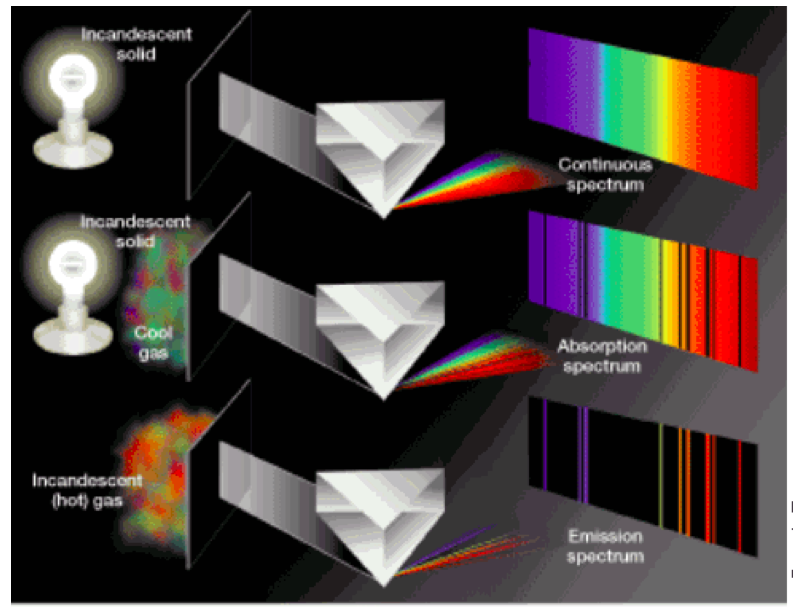
*Reading Checkpoint*

(a) What are photons?

**Spectroscopy**

When Sir Isaac Newton used a prism to disperse visible light into its component colors, he unknowingly introduced the field of spectroscopy. **Spectroscopy** is the study of the properties of light that depend on wavelength. The rainbow of colors Newton produced included all wavelengths of light. It was later learned that two other types of spectra exist. Each is generated under somewhat different conditions.

**Continuous Spectrum**

****A **continuous spectrum** is produced by an incandescent solid, liquid, or gas under high pressure. (Incandescent means “to emit light when hot.”) The spectrum consists of an uninterrupted band of color, as shown in Figure 3A. One example would be light generated by a common light bulb. This is the type of spectrum Newton produced.

**Figure 3** ***Formation of Spectra*** **A)** A continuous spectrum consists of a band of uninterrupted color. **B)** An absorption spectrum contains dark lines. **C**) An emission spectrum contains bright lines.

**Absorption Spectrum**

An **absorption spectrum** is produced when visible light is passed through a relatively cool gas under low pressure. The gas absorbs selected wavelengths of light. So the spectrum appears continuous, but with a series of dark lines running through it, as shown in Figure 3B.

**Emission Spectrum**

An **emission spectrum** is produced by a hot gas under low pressure. It is a series of bright lines of particular wavelengths, depending on the gas that produces them. As shown in Figure 3C, these bright lines appear in the exact location as the dark lines that are produced by the same gas in an absorption spectrum.

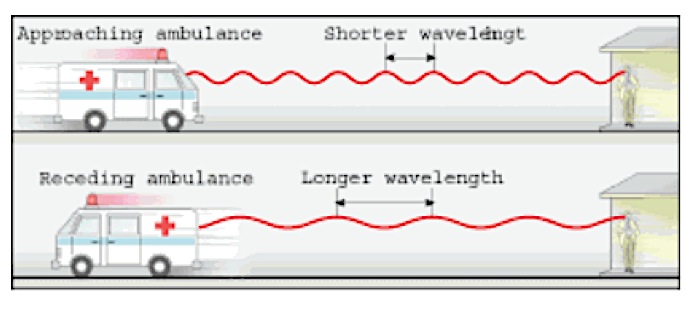
The spectra of most stars are of the dark-line, or absorption, type. The importance of these spectra is that each element or compound in its gaseous form produces a unique set of spectral lines. **When the spectrum of a star is studied, the spectral lines act as “fingerprints.” These lines identify the elements present and thus the star’s chemical composition.** The spectrum of the sun contains thousands of dark lines. More than 60 elements have been identified by matching these lines with those of elements known on Earth.

*Reading Checkpoint*

(a) What is spectroscopy?

**The Doppler Effect**

When an ambulance approaches, the siren seems to have a higher-than-normal pitch. When it is moving away, the pitch sounds lower than normal. This effect, which occurs for both sound and light waves, is called the Doppler effect. The **Doppler effect** refers to the perceived change in wavelength of a wave that is emitted from a source that is moving away or toward an object. It takes time for the wave to be emitted. If the source is moving away from you, the beginning of the wave is emitted nearer to you than the end. From the listener’s perspective the wave appears to be stretched, as shown in the model for Figure 4. The opposite is true for a wave moving toward you.



**Figure 4 *The Doppler Effect*** The wavelength of the sound of an approaching ambulance is compressed as it approaches an observer. For a receding ambulance, the wavelength is stretched out and the observer notes a lower-pitched sound. When this effect is applied to light, a shorter wavelength is noted for an approaching object and is seen as blue light. A longer wavelength is noted for a receding object, which is seen as red light.

The light from a source that is moving away from an observer appears redder than it actually is because its waves are lengthened. This effect is only noticeable to the human eye at velocities approaching the speed of light. Objects moving toward an object have their light waves shifted toward the blue, or shorter wavelength. In addition, the amount of shift is related to the rate of movement. Thus, if a source of red light moved toward you, it could actually appear blue. The same effect would be produced if you moved and the light source was stationary.

**In astronomy, the Doppler effect is used to determine whether a star or other body in space is moving away from or toward Earth.** Larger Doppler shifts indicate higher speeds; smaller Doppler shifts indicate slower speeds. Doppler shifts are generally measured from the dark lines in the spectra of stars by comparing them with a standard spectrum produced in the laboratory.

**Chapter 24 SECTION 1 Assessment**

**Reviewing Concepts**

(1) What types of radiation make up the electromagnetic spectrum?

(2) Compare and contrast the three different types of spectra.

(3) How do scientists determine the elements present in a star?

(4) How can scientists determine whether a star is moving toward or away from Earth?

**Critical Thinking**

(5) **Sequencing** Sequence the components of visible light according to wavelength, beginning with the

shortest wavelength.

(6) **Applying Concepts** Based on what you know about visible light, how do rainbows form in Earth’s

atmosphere?